March 26, 1968 C. A. BURKE ETAL 3,374,639

LEAK DETECTION AND PRESSURE RELIEF SYSTEM FOR INSULATED LIQUEFIED GAS STORAGE TANKS

Filed Oct. 25, 1966 7 Sheets-Sheet 1

FIG. 1.

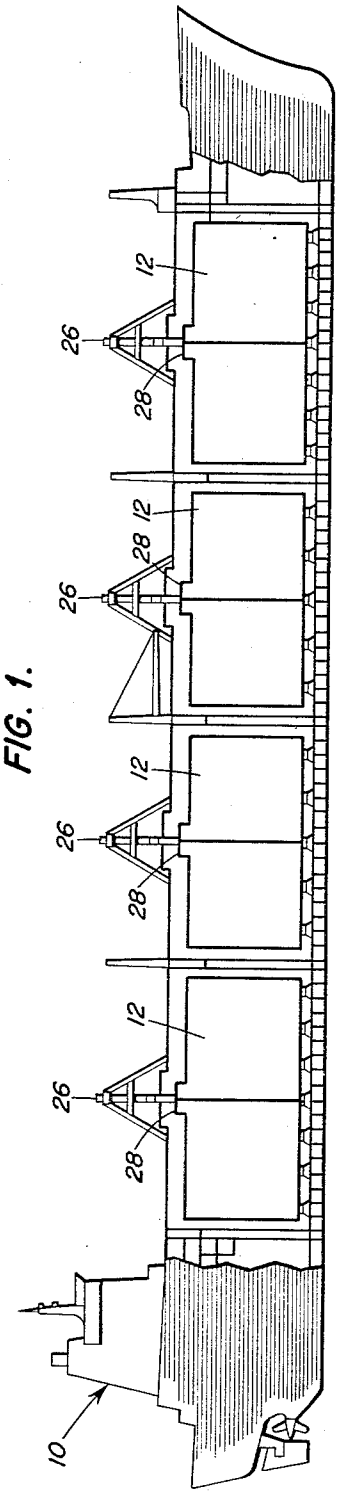


FIG. 6.

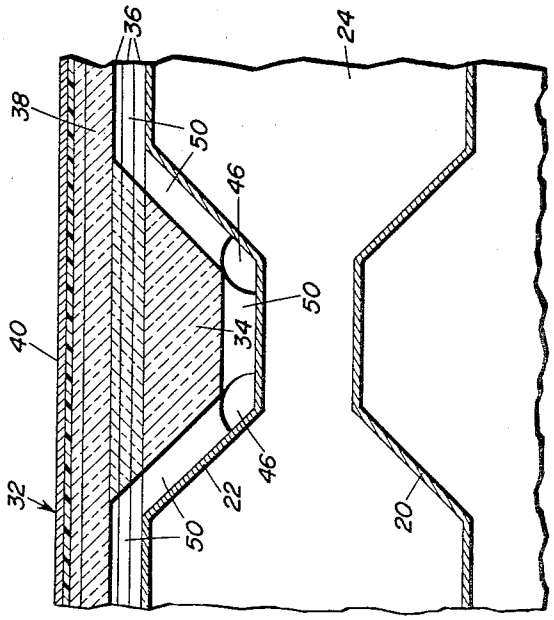
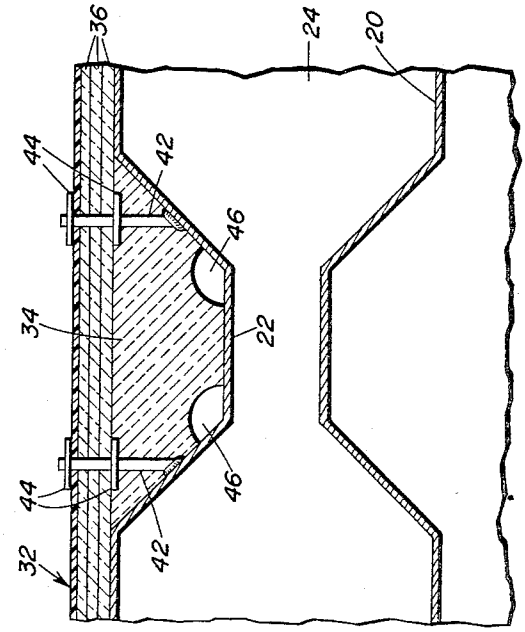


FIG. 5.



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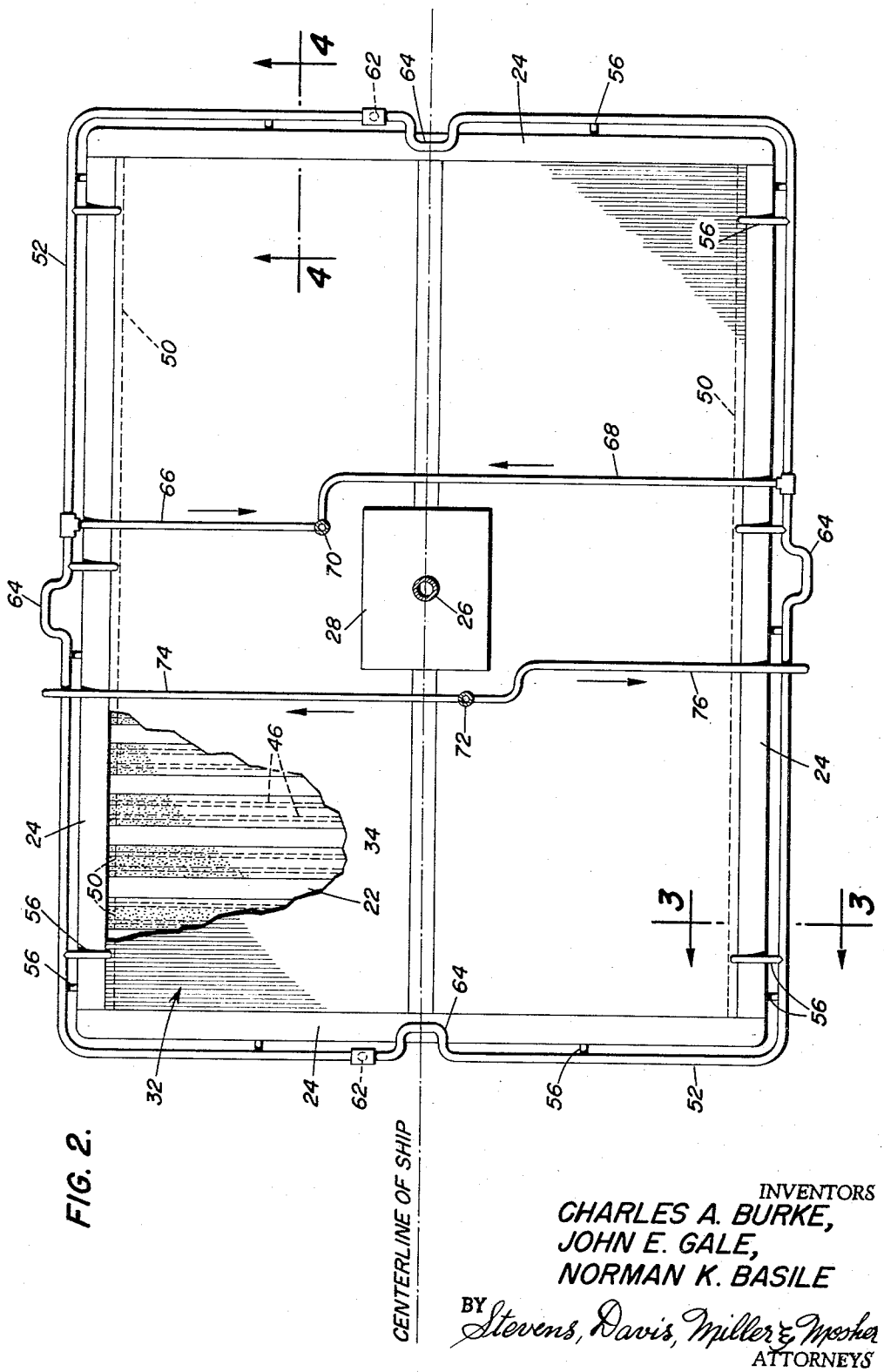


FIG. 2.

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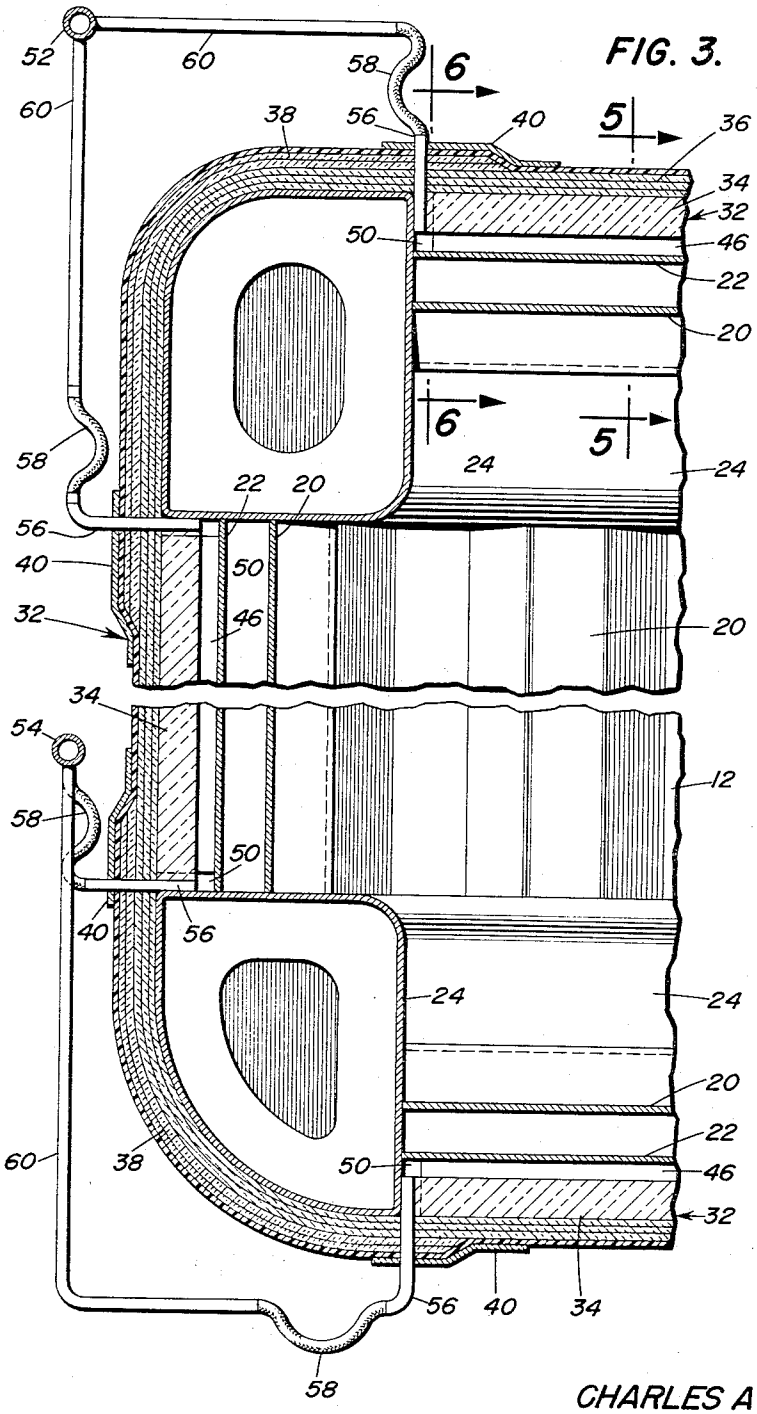
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LEAK DETECTION AND PRESSURE RELIEF SYSTEM FOR INSULATED LIQUEFIED GAS STORAGE TANKS

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FIG. 3.



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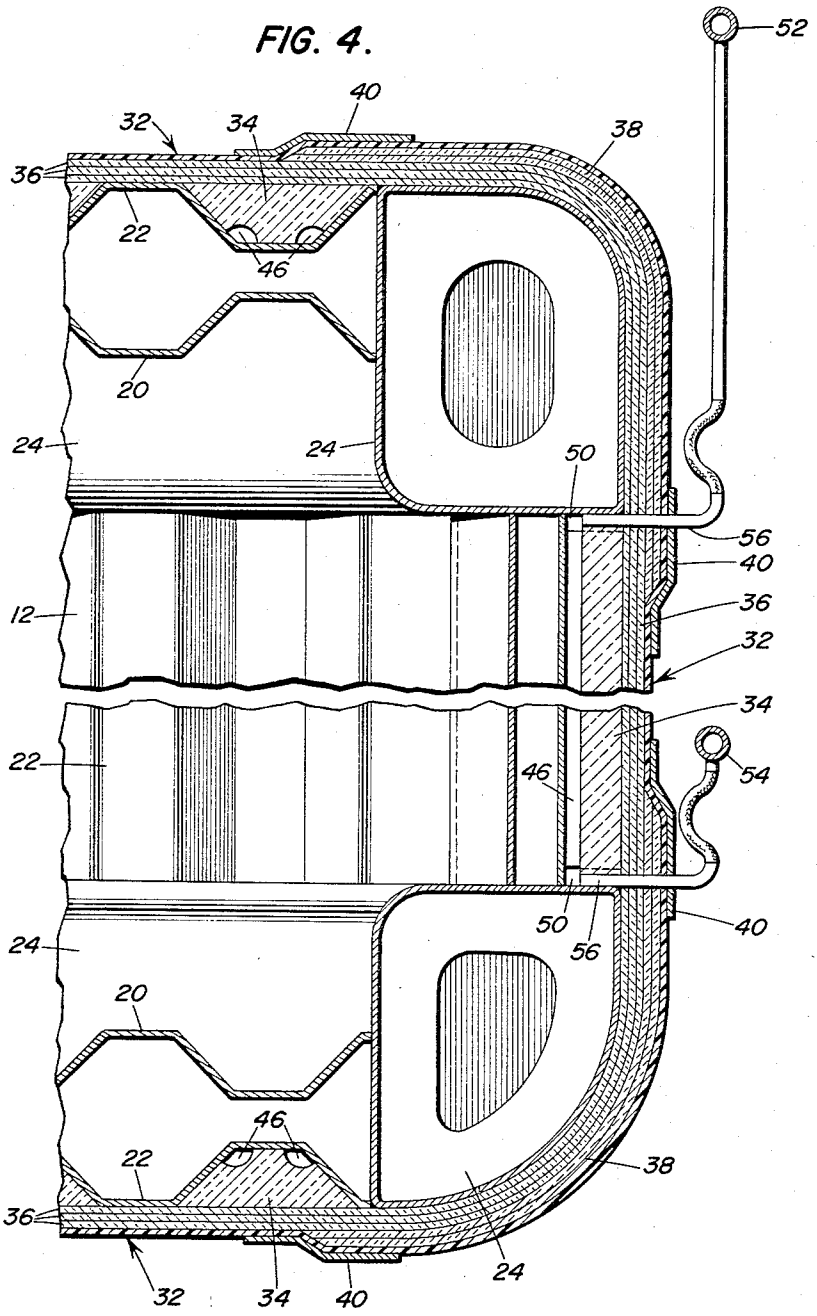
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LEAK DETECTION AND PRESSURE RELIEF SYSTEM FOR INSULATED LIQUEFIED GAS STORAGE TANKS

Filed Oct. 25, 1966 7 Sheets-Sheet 4

FIG. 4.



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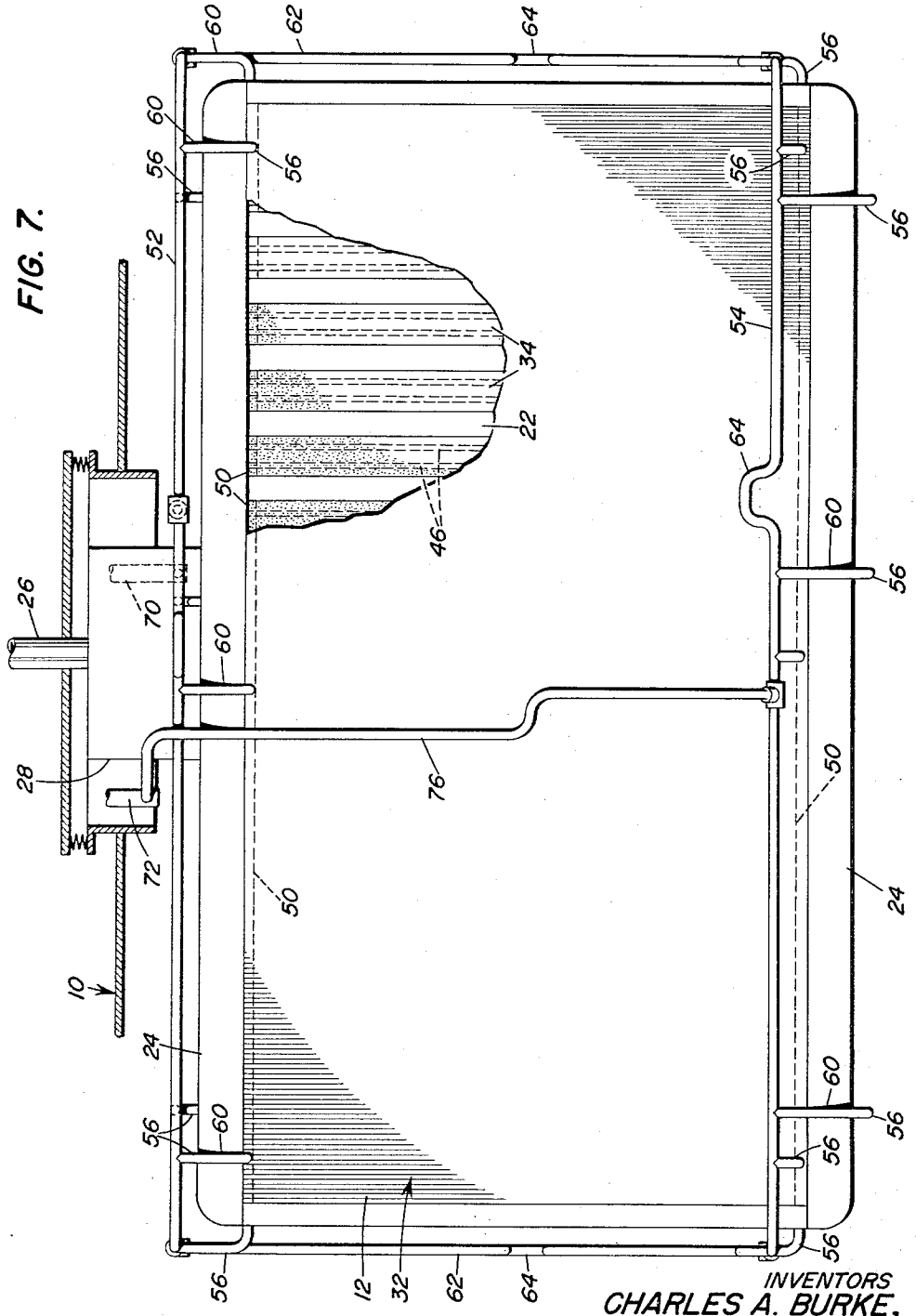
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LEAK DETECTION AND PRESSURE RELIEF SYSTEM FOR INSULATED LIQUEFIED GAS STORAGE TANKS

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FIG. 7.



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LEAK DETECTION AND PRESSURE RELIEF SYSTEM FOR INSULATED LIQUEFIED GAS STORAGE TANKS

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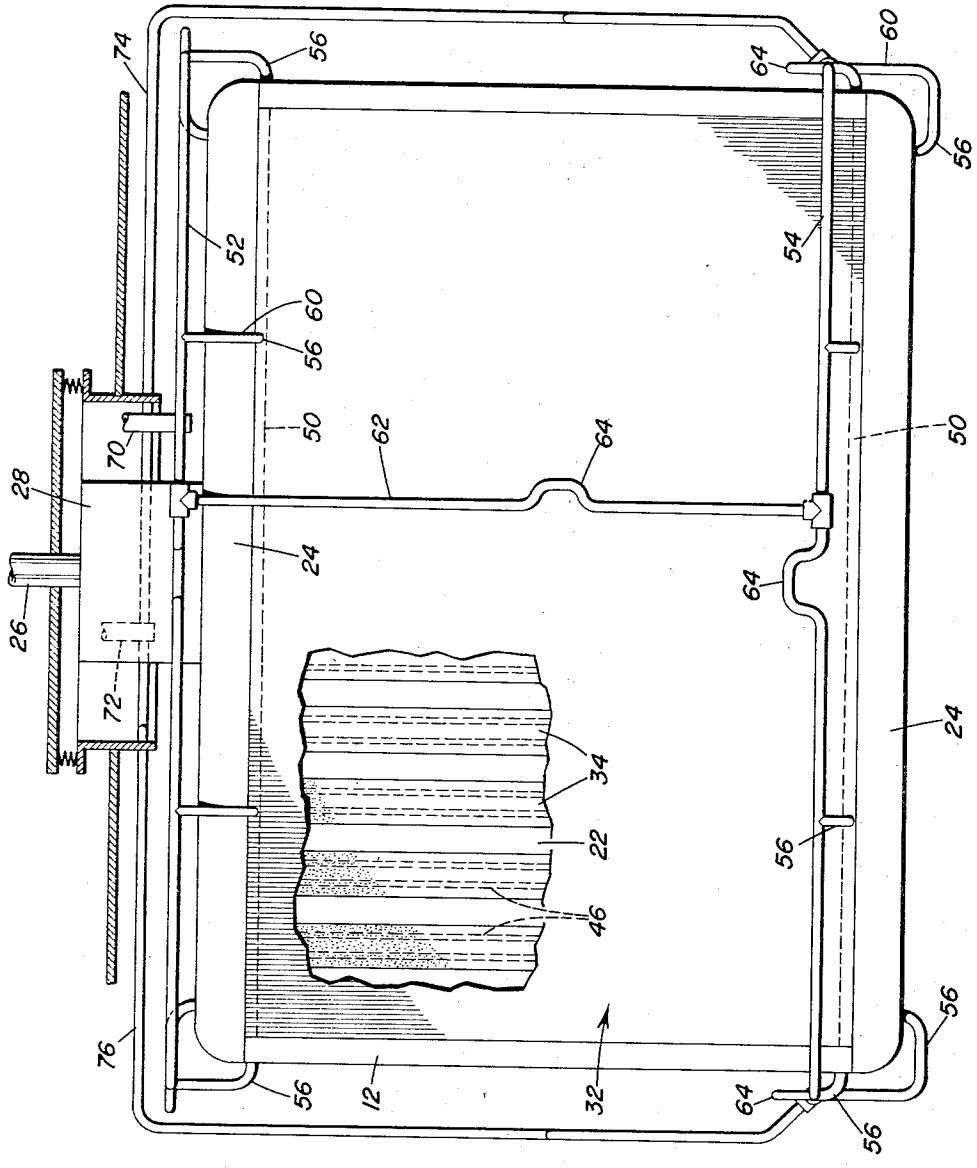


FIG. 8.

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LEAK DETECTION AND PRESSURE RELIEF SYSTEM FOR INSULATED LIQUEFIED GAS STORAGE TANKS

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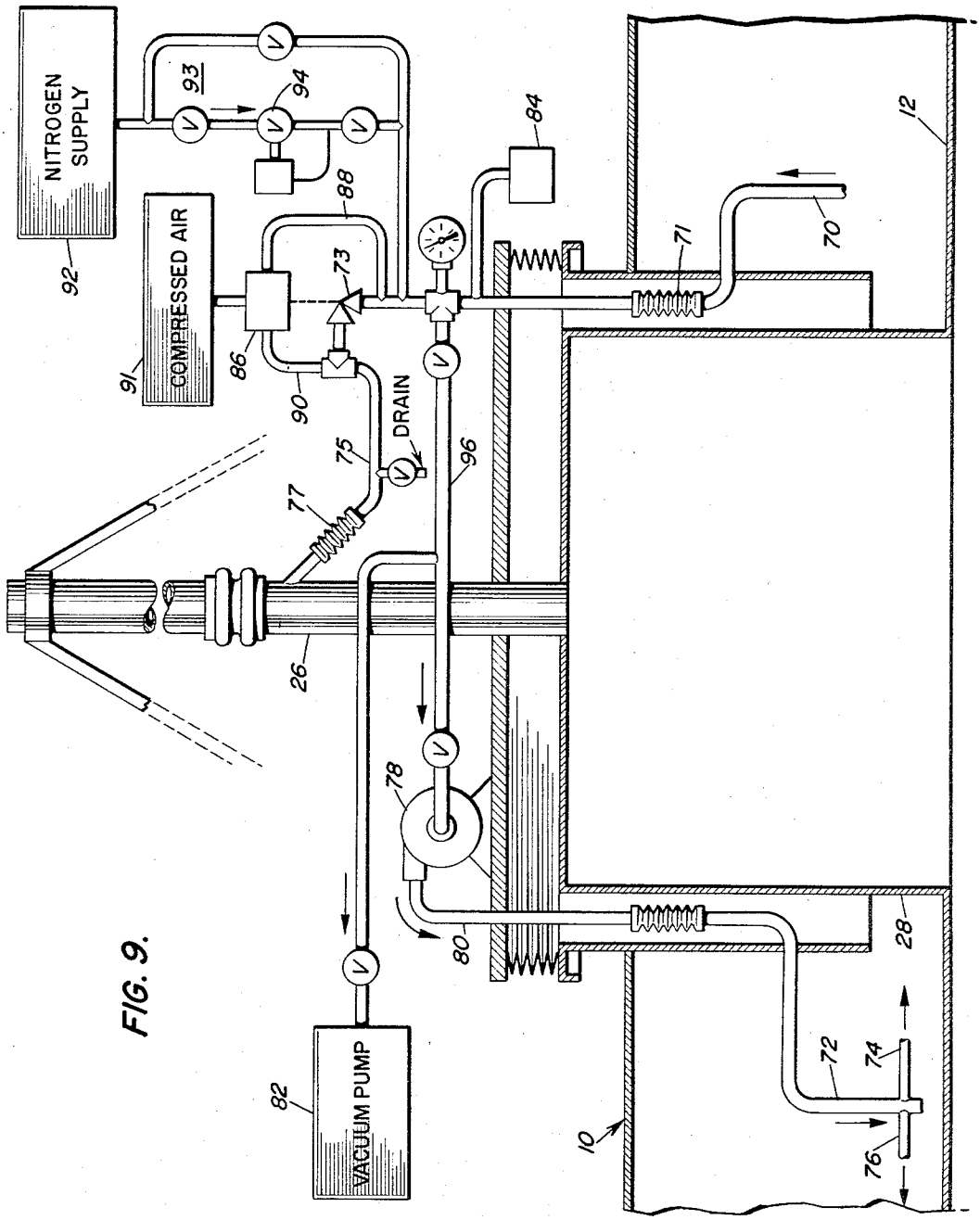


FIG. 9.

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3,374,639

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3,374,639

LEAK DETECTION AND PRESSURE RELIEF SYSTEM FOR INSULATED LIQUEFIED GAS STORAGE TANKS

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Filed Oct. 25, 1966, Ser. No. 589,360
13 Claims. (Cl. 62—45)

ABSTRACT OF THE DISCLOSURE

A tank for storing liquefied gas or the like at about ambient pressure including an outer coating of thermal insulation in which gas conveying grooves are formed against the outer surface of the tank. The insulation is gas impervious. In the event of leakage through the tank wall, vapors are conveyed through the insulation grooves to various header grooves and thereafter conveyed away from the tank so as to prevent pressure buildup behind the insulation and resulting damage thereto. A gas analyzer is provided to detect the gas within the grooves so that if cargo gas appears, a tank leak condition is indicated.

The present invention relates to a novel tank construction for carrying a cryogenic fluid such as liquefied gas at about ambient pressure, and more particularly, to a leak detection and pressure relief system for tanks of this type.

In the transportation of cryogenic fluid such as liquefied gas, various tank configurations have been designed including free standing flat and corrugated plate and single and double wall tanks supported either above or upon a bed of thermal insulation within the hull of the transport ship. With any design, steps must be taken to protect the soft carbon steel forming the ship's hull from the low temperatures of the tank and contents thereof. One such technique involves lining the inner walls and bottom of the hull with layers of insulation spaced from the outer walls of the tank. Recent developments include the new technique of hanging layers of insulation completely about the outer walls of the tank and spaced from the hull sides and ship bottom. Such an arrangement is disclosed in the co-pending patent application entitled, "Novel Insulated Tank Configuration," by Thomas F. Bridges et al., Ser. No. 539,489, filed Apr. 1, 1966, and assigned to the present assignee and incorporated here by reference.

In regard to this new design, there has been discovered the possibility that cracks developing in the tank walls could result in a leakage therethrough of gas and the entrapment thereof behind the innermost layers of insulation. With time, this gas may expand creating pressures which force the adjacent layers of insulation away from the outer tank wall. In the extreme case, it is conceivable that the insulation may be torn or broken from the wall leaving portions of the wall exposed to the mild steel ship supporting structure. This exposure creates a dangerous situation for the reason that the ship's supporting structure cannot withstand the cold cryogenic temperatures associated with the tank.

It is an object of the present invention to provide means within the layers of insulation hung about the outer wall of a tank of any configuration, said means serving to channel any escaping gas to a predetermined zone where it can be removed so as to avoid the buildup of pressure between the insulation and the tank wall.

Another object of the present invention is to provide a system which continuously monitors the leak condition of the outer tank wall and actuates an appropriate alarm accordingly.

In a preferred configuration of the present invention, the inner layers of insulation form a plurality of grooves and channels into which accumulate any gas leaking through the outer tank wall. The grooves extend along the outside of the tank wall to header channels which feed through collection headers and a relief valve to a blow-off mast. Of added advantage, a gas analyzer is located in the circulation pipe giving immediate indication of the leak condition of the outer tank wall. The detector samples a continuous flow of gas from a top collection header to determine the presence of a cargo gas leak. The sampled gas is returned to a bottom collection header. Flow is induced by a motor driven centrifugal fan located either at the tank hatch or in the fore and aft passageways below the upper deck.

Other and further advantages and objects will become apparent with the following detailed description when taken in conjunction with the appended drawings.

FIGURE 1 is a side elevation with parts broken away of a ship according to the present invention.

FIGURE 2 is a top plan view of one of the tanks according to the present invention.

FIGURE 3 is a partial vertical transverse section taken along line 3—3 of FIGURE 2.

FIGURE 4 is a partial vertical longitudinal section taken along line 4—4 of FIGURE 2.

FIGURES 5 and 6 are vertical longitudinal sections taken along lines 5—5 and 6—6 of FIGURE 3.

FIGURES 7 and 8 are side and front elevations respectively of the tank of FIGURE 2.

FIGURE 9 is a diagrammatic illustration of the blow-off mast and associated control systems for the pressure relief and gas detection system.

FIGURE 1 illustrates a ship generally designated as **10** fitted with four cargo tanks **12**, each being formed of a material such as aluminum or nickel-steel alloy so as to withstand cryogenic temperatures such as that of liquefied methane or the like. A blow-off mast **26** associated with each tank is mounted on the upper deck of ship **10**, preferably over the central trunk **28** of the tank. Each tank is of free standing construction and is supported above the hull bottom on a plurality of insulated pillars. The preferred tank includes a double barrier design in the form of an inner wall **20** and a spaced outer wall **22** joined at the tank edges by a plurality of box girders **24**. It is also preferred, but not essential for the present invention, that walls **20** and **22** be corrugated with the mutually facing corrugations aligned. The corrugations for the side walls of the tank extend vertically and the corrugations for the top and bottom of the inner and outer tanks extend athwart ship.

In order to reduce heat transfer through the tank walls, thermal insulation **32** blankets the entire outer tank wall **22**. The insulation **32** includes a plurality of insulation blocks **34** with profiles shaped such that the blocks **34** fit flush within the spaces defined by the corrugations of outer wall **22**. Additional layers **36** of 1-inch thick insulation cover the exposed parts of outer tank wall **22** and the face of blocks **34**. Blocks **34** and layers **36** are held to the outer tank wall **22** by a plurality of projecting rods **42** extending through blocks **34** and the layers **36** and a plurality of clip washers **44** secured to rod **42**. Blocks **34** and layers of insulation **36** are formed of 90% closed cellular insulation so as to prevent the passage therethrough of any gas that may leak through cracks in the outer tank wall **22**. Notwithstanding the gas and impervious nature of the insulation, a vapor barrier is deposited on the outer face of the insulation **36**. As better seen in FIGURES 3 and 4, a buildup of additional layers of insulation **38**

is arranged at the tank edges covering box girders **24**. Aluminum flashing **40** overlaps the edges of the buildup and is attached to the insulation layers **36**. For further disclosure and description of the tank construction and insulation arrangement therefor, reference is made to patent application identified above.

According to the present invention, blocks **34** are cut at their innermost corners to define a pair of longitudinal grooves **46** which cooperate with the outer tank wall **22** and to form conduits which extend in the same direction as the associated corrugation. Thus, grooves **46** run athwart ship at the top and bottom of the tank and vertically along the sides of the tank.

With reference to FIGURE 2, the grooves along the top and bottom of the tank dead end in a location near the ship's center line. Although part of blocks **34** and insulation **36** abut the box girders, the end blocks **34** and layers of insulation **36** are cut away to form a header grooves **50** which are defined on one side by part of the associated box birder **24**. As better seen in FIGURE 6, each header groove **50** runs along the profile of the outer tank wall **22**. The outboard ends of grooves **46** at the top and bottom of the tank communicate with and feed ino the longitudinal extending header grooves **50**. Transverse grooves **46** communicate with header grooves **50** which extend along the side and end walls of the tank. Although it cannot be seen from the drawings, header grooves **50** terminate at each end at a respective vertical box girder **24**.

In the event there is any gas leakage through the outer tank wall **22**, the leaking gas will accumulate between the insulation in the tank wall, and under its own pressure it will eventually find its way to the nearest groove **46**. In this way, the gas is bled away from the source of the leak to the header grooves **50** so as to prevent a pressure buildup between the insulation and outer tank wall **22**.

In order to prevent leaked gas from creeping between block **34** and insulation **36**, the mutually contacting surfaces thereof may be secured together with an adhesive such as any suitable epoxy.

The tank further comprises a top collection header **52** and a bottom collection header **54** which are connected to the ship's supporting structure and extend about the periphery of the tank at its respective vertical location. As better seen in FIGURES 3 and 4, pipes **56** extend through the layers of insulation and communicate with the header grooves **50**. Pipes **56** feed a flexible hose connection **58** which in turn feeds the collection headers **52** through pipe sections **60**. The collection headers are fluidly connected together by a pair of vertical risers **62**, one located at the forward center line of the tank and the other at the aft center line of the tank. Each riser **62** as well as the collection headers **52** and **54** are provided with expansion joints **64** to permit thermal growth as required.

At the top of the tank, a pair of pipes **66** and **68** are connected from opposite sides near the tank midline of the top collection header **52** to an outlet connection **70**. An inlet connection **72** feeds a second pair of pipes **74** and **76** which extend outward across the top of the tank and down opposite sides thereof at a location near the midline of the tank. Pipes **74** and **76** are connected at their lower ends with the bottom collection header **54**.

Referring now to FIGURE 9, outlet connection **70** feeds through a flexible connector **71** which in turn feeds through a differential relief valve **73**, a blow-off pipe **75** with a flexible connection **77** and out through the blow-off mast **26**. A centrifugal fan **78** is connected to draw through a recirculation line **96** from the input line to the pressure relief valve **73** and feed to line **80** provided with a flexible connection to the input connection **72**. Cut-off valves are provided in the recirculation line generally as shown. In addition, vacuum pump **82** is also connected to the input line to fan **78** through an appropriate cut-off valve. With this arrangement, the valves can be positioned so that the fan **78** when energized draws from connection **70** and delivers to connection **72**, and alternately, with fan **78** de-energized and vacuum pump **82** energized suction can be drawn from connection **70** or connection **72**.

If desired, suitable connections can be included on line **96** for connecting a manometer and a pressure gauge.

In order to obtain an immediate indication of a cargo gas leak condition in the secondary barrier, a gas detector **84** is coupled to the outlet line connected to outlet connected **70**. Any suitable conventional gas detector can be used and it should be understood that these detectors are well known and readily available in commerce. One suitable methane gas detectr is of the infra-red type as manufactured by Mine Safety Appliances, Inc. and will detect concentration as low as 0–50 p.p.m.±1% on a continuous basis.

The differential pressure release valve **73** is controlled by a pneumatic actuator **86** which senses the upstream-and-downstream pressure differential through lines **88** and **90** respectively. Actuator **86** is preferably set to energize or open valve **73** when the pressure differential sensed is, for example, five inches of water and reset valve **73** when the pressure differential drops to one inch of water. Actuation is accomplished by connecting a source of compressed air or the like **91** with the movable mechanism of valve **73**.

A source of nitrogen gas **92** is connected to the line coupled to the outlet connection **70** through a valve system **93**. Valve system **93** is capable of isolating source **92** from outlet connection **70**, or alternately, if the valves are appropriately set, a pressure sensitive valve **94** connects the source **92** to the recirculation line **96** whenever the pressure therein drops below one inch of water. This action prevents an under pressure buildup in the groove system. With vacuum pump **82** energized and the appropriate valves closed, the entire system of vertical grooves **46** and groove headers **50** as well as the collection headers and associated pipes and risers can be purged or flushed with the inert gas from nitrogen supply **92**. Fan **78** can be alternately used to flush the system with inert gas from supply **92** with a different valve setting.

In operation, after the system is purged with inert gas, vacuum pump **82** is de-energized and fan **78** is energized to circulate the gas through inlet connection **72**, pipes **74** and **76** to the bottom collection header **54**, up the vertical riser pipes **62** to the top collection header **52**, through pipes **66** and **68** up through the outlet connection **70**, past the gas analyzer **84** and back to the fan **78**. With a no-leak condition in the outer wall **22**, the pressure in circulation line **96** and grooves **46** remain between the one and five inches of water and pressure release valve **74** remains closed. If during cool down procedures, the groove pressure drops below one inch of water, valve **94** opens to supply additional volumes of inert gas.

In the event a leak condition develops in the outer tank wall **22** and cargo gas leaks therethrough, cargo gas will travel under its own pressure to the nearest groove **46** in the manner described above and then to the header groove **50** where it is withdrawn to the nearest collection header **52** or **54** where it immediately enters the circulating stream under the influence of fan **78**. Gas analyzer **84** immediately detects the presence of leaked gas as soon as the same flows from connection **70** to circulation line **96**, and detector **84** accordingly energizes the appropriate alarms. In this way, gas leakage through even the smallest of cracks in outer tank wall **22** is detected even though the pressure in the system has not reached five inches of water.

However, in the event the leak in outer wall **22** is substantially large with an appreciable gas leakage therethrough, pressure buildup in the appropriate grooves and collection headers may exceed five inches of water almost instantaneously with the development of the leakage and relief valve **73** is opened to relieve excess pressure through blow-off masts **26** approximately simultaneously with the indication of a cargo gas leak by gas analyzer **84**. In any

event, the excess pressure between the thermal insulation and the outer tank wall **22** cannot exceed five inches of water by virtue of the operation of pressure relief valve **73**. As described above, this action prevents the thermal insulation from being blown or forced from the tank wall and in addition prevents the cargo gas from reaching the supporting ship's structure.

It should be understood that various modifications can be made to the herein disclosed example of the present invention without departing from the spirit and scope thereof.

It is claimed that:

1. A tank for storing liquefied gas or the like at about ambient pressure, said tank having thermal insulation contacting the walls thereof so as to prevent heat transfer through the walls of the tank, said thermal insulation being gas impervious, an elongated groove defined on an inner surface of the insulation and bounded by a part of the outer face of the tank wall, said groove being normally isolated from the interior of the tank, pipe means having one end communicating with said groove and the other end communicating with the ambient to bleed away from the tank any gas leaking through the tank wall and into said groove so as to prevent buildup between the insulation and the tank wall.

2. A tank as set forth in claim **1** wherein a plurality of said grooves are provided spaced from each other and extending throughout substantially all zones of each wall of the tank, at least some of the grooves at each wall being arranged generally parallel to each other, the insulation further defining at least one header groove on each tank wall, each header groove extending across and communicating with at least some of the plurality of said grooves, the pipe means being connected to communicate with each of said header grooves so that an excess pressure buildup of cargo gas leaking through any crack developing anywhere in the tank wall is prevented by virtue of bleeding the gas through the grooves adjacent the leak to the associated header groove and out through the pipe means.

3. A tank as set forth in claim **2** wherein a pressure relief valve is located in said pipe means, and a pressure relief valve actuator means is provided to sense the pressure within the groove system and actuate the pressure relief valve when this pressure exceeds a predetermined value.

4. A tank as set forth in claim **2** further comprising a gas analyzer connected to said pipe means to analyze any gas flowing from the grooves, said analyzer energizing an alarm whenever it detects cargo gas.

5. The tank as set forth in claim **2** wherein said pipe means comprises a first collection header and a second collection header, first pipes connected to first header grooves feeding the first collection header and second pipes communicating with second header grooves feeding the second connection header, third pipes coupling said first and second collection headers, circulation means when energized drawing gas from one of the collection headers past the gas analyzer and feeding the analyzed gas back to the other of said collection headers.

6. A tank as set for in claim **5** wherein a supply of inert gas is coupled to said circulation means through a cut-off valve system.

7. A tank as set forth in claim **6** wherein a vacuum pump is connected to the circulation means through a cut-off valve.

8. A tank as set forth in claim **6** wherein said circulation means includes a fan.

9. A tank as set forth in claim **3** wherein the pressure relief valve, when open, is connected to feed the blow-off mast for the tank.

10. A tank as set forth in claim **2** wherein the tank walls are corrugated, said insulation formed by blocks fitted within the corrugations and the blocks being cut to define one of the grooves such that the groove extends along the corrugation, additional layers of insulation secured to blanket the outer parts of the tank wall and the outer parts of the insulation blocks.

11. In combination with the tank as set forth in claim **10**, a ship, said tank supported within the hull of the ship, the corrugations and grooves at the top and bottom tank walls extending athwart ship and those of the upstanding tank walls extending upward, one header groove arranged near the top of each upstanding tank wall and one header groove arranged near the bottom of each upstanding tank wall, the grooves on each wall communicating with both of the associated header grooves.

12. The tank as set forth in claim **2** wherein said pipe means includes expansion joints to permit thermal growth of the tank relative to a part of the pipe means.

13. A combination as set forth in claim **11** wherein said pipe means comprises an upper collection header communicating with the upper header grooves and a lower collection header communicating with the lower collection header grooves, a pair of riser pipes located at opposite ones of the fore and aft walls of the tank connecting the lower collection header with the upper collection header, a pair of pipes coupled from an outlet connection to opposite ones of the outboard sides of the upper collectin header, an inlet connection, a pair of pipes coupled from said inlet connection to opposite outboard sides of the lower collection header, circulation means connected from said outlet connection to said inlet connection, said tank further comprising an inner tank wall spaced from the tank outer walls to which said insulation is secured, box girders located along all edges of the tank, each groove having at least one end terminating at a box girder, and said header grooves being located adjacent a box girder.

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